SEMI-AUTONOMOUS RESCUE TEAM 2023 TDM

Team Description Materials 2023

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Semi-Autonomous Rescue Team

Team Description Materials 2023

Logistical Information

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1. Introduction

The Semi-Autonomous Rescue Team (herein known as the S.A.R.T.) is a group of STEM enthusiasts originally formed in early 2015 with the intent of developing and creating a robot capable of competing in the 2016 Rapidly Manufactured Rescue Competition (RMRC) at RoboCup in Leipzig, Germany.

2. Reflection on experience at RoboCup in 2021 and 2022

S.A.R.T. participated in the RMRC at RoboCup remotely in 2022. S.A.R.T. was tasked with creating a robot capable of travelling through a small course filled with various obstacles. Points were awarded based on the number of times that the robot could traverse back and forth through the course within a specific time limit. The robot was controlled remotely by a driver who was only able to see through cameras and any other sensors attached to the robot. Since S.A.R.T. was competing remotely in 2022, alternate cameras had to be set up to record each of the runs for the RMRC. The teleoperator was not allowed to view these cameras during competition runs, the sole purpose of these cameras was to record the robot from a birds-eye view for submission.

We worked tirelessly day and night to achieve our projected goals and due to our hard work, we successfully reaped the rewards. S.A.R.T. came out with a total of 4 significant recognitions in the RMRC. We were awarded with our robot having the best mobility and manoeuvring in the competition. Our robot was able to travel the course with ease and the turning ability was superb. This was only one accolade we received though. Another feature of the robot the team was praised for was the exploration and mobile sensing of the robot. One final aspect of our submission we were rewarded for was our video presentation. S.A.R.T. had the most thorough and well-presented video in the competition. Although we were rewarded with these three separate accolades, there was one prize that was won which holds far greater importance. The team was rewarded with the Open Source and Innovation award. This specific award is granted with a trophy and is the most prestigious and sought-after prize in the RMRC. Our hard work and tireless nights were paid off as S.A.R.T. achieved our goals and more, and the team will be looking to follow up on that impressive performance in 2022 where we will compete remotely once again.

3. System Description

Hardware

'Nibbler' was introduced in 2023 as the next generation of S.A.R.T. robot. It had seen a number of improvements and modifications when compared to its predecessor, Flexo.

Arm

Figure 1 – Render of Arm Claw

Figure 2 – Render of Arm (Full Assembly)

Chassis and Tracks

In this iteration of S.A.R.T., most of the main components of the chassis and tracks were kept the same from the Bender robot. The first section we decided to keep the same was the material of the robot. The Bender robot's chassis was constructed using both 3D print and acrylic materials. The reason for this was because it was easier to design and create the chassis if it was 3D printed. We were able to design the chassis using Fusion 360 and directly export the file and 3D print it making the whole process much more efficient. The acrylic was used for the bottom and the top of the Nibbler robot. This material was much easier to acquire and cut to the desired size. Moving away from the material of the chassis, the robot was also designed to be much narrower. This was done to fit the arm on top of the robot without causing any issues of the robot being too tall so the arm would get caught on things. We also had the front and back of the robot be much more rounded so that when it is travelling over various obstacles the Chassis won't restrict its ability to get over the obstacles.

The tracks on the Nibbler robot are the same as both the Flexo and Bender robots as they have been proven to be very effective in competition test methods. One issue that has always encountered S.A.R.T. robots is sand. Sand gets lodged in the tracks and when that happens the tracks fail to move and a large amount of stress is placed on the motor controller. To combat this, we drilled holes in the tracks to allow the sand to leave the tracks to ensure the tracks can work without interruption. When we tried to install the tracks onto the robot, we realised that they were too tight and if they were to be used, they would place too much stress onto the motor controller. In this discovery, we also found out that each link of the tracks is a different size. To ensure that the tracks are not too tight, we needed to compare each link and separate by size. We then used this to create the longest possible tracks to use on the robot. Once that was done, the tracks were much less tight and were ready to use on the robot. Finally, we are also using the same motors we used in the Flexo robot. This is because the motors worked well in last year's iteration and there is no reason to change the motors.

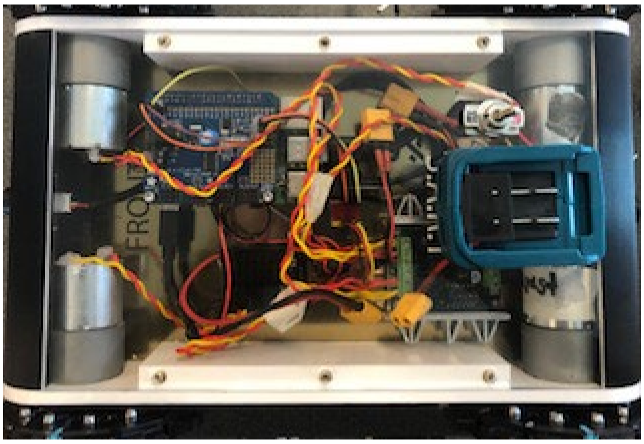

Figure 3 – Finished chassis of Nibbler Robot

Figure 4 – finished chassis of Flexo robot.

Bender Flexo Nibbler Chassis Comparison

While all three robots are built on roughly the same base, there are plenty of notable changes in the design of the chassis. In terms of Bender vs. Flexo, the most obvious change is the addition of the arm. This arm was the first iteration of S.A.R.T. arms and is currently what Nibbler's arm is being based on. In addition to the arm, the battery's angle has been noticeably lowered to accommodate this additional bulk on top of the robot.

Nibbler and Flexo on the other hand are a lot more alike, Nibbler is more like an improved and refined version of Flexo. The most notable changes between the two are Nibblers clear acrylic top, making it possible to see inside of the robot without having to take it apart, and the new and improved arm. While the render shown below doesn't show Nibbler's new arm, the idea was based off Team TUPAC's robotic arm, which had a three-prong gripper design which inspired our team to try something similar. Other than the three-prong gripper, the arm design stayed loyal to the original arm design, just with all round improvements.

Figure 5 - Bender (Left) Flexo (Middle) Nibbler – No arm (Right)

Figure 6 – Comparison of Nibbler claw (Left) and Flexo claw (Right)

Control System

In contrast to previous years, the new robot and control panel will be using the new 'Sights Lite', which aims be a more simplified and stable version of the original Sights software. The robot will be controlled using the same control scheme as previous years, with the movement using either the arrow keys or WASD, and the number pad for the controlling of the arm. In addition to the control scheme, many other features were carried over from last year's robot, namely the Sabretooth motor controller, and the Raspberry Pi servo hat used to control the servos and motors. This year we once again used the previous fixes done which made using the Sabretooth possible with the Raspberry Pi, which can be found in our previous TDM.

Control Panel

Contrary to previous control panels, this year's control panel will consist of a much simpler design, instead using a laptop as the brains of the control panel, along with a basic USB monitor, wireless access point, a full-size keyboard (for the number pad), and a Ryobi drill battery to outlet adapter. A notable change when compared to previous years in our networking of our wireless access point is in the use of a tripod designed for a camera. The tripod allows our access point to be positioned higher than most other team's AC's, which means there will likely be significantly less interference and provide a much better connection with the robot.

The USB monitor and the access point were both powered by the Ryobi drill battery, while the laptop was powered through its inbuilt battery. The decision to change the control panel design was mainly down to 2 reasons, the first reason was due to the compactness and might lower weight of the new panel, as a majority of the weight from the old panel was from the uninterruptable power supply (UPS), along with the much bigger pelican case, whereas now everything is powered through the drill battery which is much lighter and smaller than the UPS. The second reason is the simplicity of the new panel, with only a few cables connecting each component. The whole panel was simplified not only make construction simpler for the people in the S.A.R.T. team, but also making setup simpler for first responders as everything is relatively straight forward in where they go.

Figure 7 – New Control System for Nibbler robot

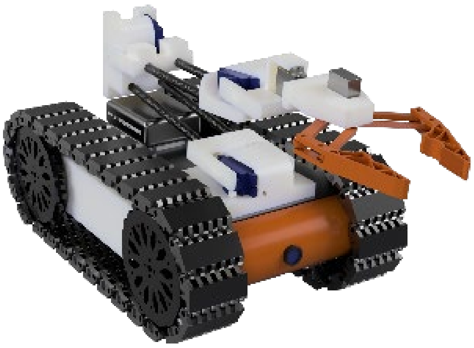

Figure 8 – Flexo Render

Software

Vision

The S.A.R.T. robot has multiple capabilities regarding interpretation of its surroundings, including recognition of Hazmat warning signs and reading of QR codes (Figure 9, 10). All our computer vision software runs on the control panel computer, using video feed received from the web socket server on the robot. This allows us to offload computations from the robot, preserving its computation power.

Our QR code reading program is a python script that uses the "pyzbar" package and its in-built QR code reading function. We apply rotation to the image at many angles and apply pyzbar to each rotation to increase efficiency. The output of this script can be seen in Figure 8.

Figure 9 – QR Code Reading

Our hazmat detection python script is a two-stage process running on the control panel. We first apply a YOLO v4 object detection model, trained on custom data, to calculate the location of the sign in the image. Once we have found the location of the sign, we apply a K-nearest-neighbours (with K=1) test (to the region of the image found by the YOLO v4 model) to classify the sign. We use sample sign images as our KNN point cloud. The final output of this process can be seen in Figure 7. The biggest advantage of this method is that the YOLO v4 model only calculates position and does not do classification. Doing classification in the YOLO v4 model would require roughly 20x more training data to achieve the same accuracy.

As for multithreading in the hazmat detection python scripts, we have continued using what was experimented with last year with running every comparison check (between sign samples and camera cutout) on separate threads. Additionally, we've added several improvements to further increase detection speed.

Figure 10 – Hazmat Detection

4. Operational Procedures

Setup

The setup process of the robot and control panel was designed to be as simple as possible. As mentioned previously, first responders in a rescue situation typically rate 'ease of use' highly amongst the requirements of a rescue robot. Thus, one of our core design philosophies for user experience was simplicity, meaning the setup process should be straightforward and intuitive.

Mission Strategy

During operation, the teleoperator has primary control of the robot using their choice of a keyboard or any compatible controller, with easy switching between robot driving and arm operation with a single button press. The teleoperator's primary vision for navigation will be the optical cameras however the suite of other sensors including map of the environment are displayed on the control panel so that the teleoperator has all the information necessary to control the robot.

Given that in a rescue situation, resetting or freeing the robot of an obstacle is not possible, this means that the teleoperator really only gets one attempt at the rescue situation so extreme caution has to be taken. For example, in a disaster situation, visibility of the path ahead may be blocked by obstacles or debris, meaning the path may be unknown to the operator, it is in the best interest of the teleoperator and the entire rescue operation to perform a risk analysis. Given that the stakes are incredibly high as the operator has little opportunity to reset the robot in a real-world situation, backtracking in an attempt to find a less risky and safer route is to be taken. Although this backtracking will likely result in a slower response time, it is the best outcome overall, as if the teleoperator makes the decision to take the risk and venture without aid from the robot's cameras, the robot is of no use whatsoever if it is stuck and cannot proceed into the situation, collecting valuable intel that can prove extremely useful in rescue operations.

Referring back to the risk analysis performed by the teleoperator, it is not always possible or viable to backtrack in an attempt to find a safer route, given situation-specific individualities. This is why it is not a concrete rule to backtrack in an attempt to find a safer way, as in some situations, the risk of venturing into a situation with minimal to no aid from the robot's cameras is less than the risk if the robot does not reach the destination in a certain amount of time. Because of this potential, the decision is left up to the telecommunicator who is operating the robot to make the decision in order to achieve the most desirable outcome given the constraints and individualities of the situation.

Pack-up

Once the robot has been recovered, the power-off process is relatively simple, with four main steps. Step 1 is to safely shut down the robot using the power options in the SIGHTS lite interface. Step 2 is to cut power to the robot by removing the Makita drill battery located near the rear of the robot. Step 3 is turning off the control panel using the usual way in the desktop operating system. The final step involves, power can be cut by removing the Ryobi drill battery located inside the control panel. Additional pack up steps may include placing the robot in its foam-lined hard carry case, which would require the robot's arm to be removed before storing in the carry case. o

5. Experiments and Testing

The SART uses a range of test methods to improve the functionality of the robot. These test methods are of modular design to test a range of engineering methodologies and validate changes to the robot. The First stage of testing is utilising a flat box which is used to simulate driving ability on 'flat ground', this test method was primary used to test camera angles and locations. Second test method involved a range of vertically angled platforms which allowed the S.A.R.T to test the rigidity of the chassis and validate its ground clearance.

The third test method was an adaptation of the second featuring more gradual steps to softly test the robot's functionality. Lastly, the fourth test method involve the S.A.R.T using a range of PVC pipes to simulate log and or smooth climbs. This method was far by the hardest and allowed us to test the robot in its entirety (with the arm). The use of these test methods has greatly improved the functionality of the robot through rigorous engineering physical testing.

6. Future Developments

Future developments will continue to focus on vision processing and autonomy. This will include taking advantage of our new hardware's capabilities in machine learning and vision processing to improve our autonomous functionality and computer vision processing. In future we would like to put significant development into a new innovative control interface, utilising virtual and augmented reality technologies to provide a significantly improved interface between the teleoperator and the robot.

7. Conclusions

The S.A.R.T Nibbler robot represents an improved design of the previously created robot by observing what parts of the robot needs to be improved upon and structuring the design process around those areas. The arm is still present on the robot to enable our robot to undergo dexterity and manipulation tests. The addition of a robotic arm to this iteration not only allows us to compete in more tests and therefore gain more points in the competition, but also expands the diversity of applications of our robot in rescue situations.

8. References

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9. Appendix

Component	**Price (USD)**	**Quantity**	**Total (USD)**
Raspberry Pi 4	$ 45.00	1	$ 45.00
MLX90640 IR Camera	$ 66.72	1	$ 66.72
ELP 5MP HD USB Autofocus Camera	$ 56.23	3	$ 168.69
Adafruit SGP30 CO2 / TVOC Sensor	$ 19.95	1	$ 19.95
MLX90614 Infrared Temperature Sensor	$ 7.57	1	$ 7.57
50:1 Metal Gearmotor 37Dx54Lmm 12V	$ 35.00	4	$ 140.00
2-pole rotary switch	$ 6.16	1	$ 6.16
Cables	$ 17.11	1	$ 17.11
Track	$ 25.11	3	$ 75.33
Servo Tubing Connector	$ 6.95	1	$ 6.95
Carbon Fibre Tube (1m x 24mm)	$ 30.00	1	$ 30.00
Acrylic Sheet (4mmx400mmx400mm)	$ 10.00	1	$ 10.00
Gripper	$ 40.00	1	$ 40.00
Turnigy 1300 mAh 3S 25C Lipo Pack	$ 12.87	2	$ 25.74
Ultimaker ABS 3D Printer Filament 1kg spool	$ 32.00	1	$ 32.00
Quanum 12V-5A (7.2 - 25.2V) Dual Output UBEC	$ 10.25	1	$ 10.25
Sabertooth 2x12 Dual Motor Driver	$ 97.98	1	$ 97.98
Adafruit 16-Channel PWM Servo HAT Raspberry Pi	$ 23.96	1	$ 23.96
Total			**$823.41**

Component	**Price (USD)**	**Quantity**	**Total (USD)**
SE830 Waterproof Protective Case	$87.00	1	$87.00
UDOO x86 Ultra	$267.00	1	$267.00
Energizer AC Sine-Wave Inverter	$50.64	1	$50.64
AOC E1659FWUX USB Monitor	$92.38	1	$92.38
Ubiquity Unifi AP AC Pro Access Point	$148.84	1	$148.84
Power-Over-Ethernet Injector	$8.00	1	$8.00
Microsoft All-In-One Media Keyboard	$45.60	1	$45.60
Turnigy 4000mAh 4S LiPo Battery	$36.95	2	$73.90
Acrylic Sheet (3mm)	$20.00	1	$20.00
Power Button	$3.00	1	$3.00

Total	**$796.83**